

Traumatic Spinal Cord Injuries

*A descriptive study of the treatment chain at the Ullevål and
Sunnås hospitals*

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Introduction

Injuries to the spinal cord leave people injured and disabled for life. Scientists worldwide are working to literally bridge the gap and facilitate the regeneration of damaged nervous tissue essential for regaining function. These initiatives are closing in on the secret to stimulating regeneration and may some day provide tremendous changes to the treatment regimens offered to patients with spinal cord injuries.

Although there has been a continuous improvement of the treatment offered to patients who sustain spinal cord injuries (SCI), there is still no cure once the damage is done. Growing understanding of the biochemical and cellular processes that occur in the damaged spinal cord may yield advances that improve the entire treatment chain from emergency care to rehabilitation. Such knowledge may help emergency medical services (EMS) and emergency room (ER) personnel to limit secondary damage and may help neurologists devise methods for converting spasticity to voluntary movement. Finally, the embryonic environment that facilitates the development of the central nervous system may be replicated to provide the means for repairing a damaged spinal cord in an adult organism.

The development of improved treatment regimes will require a continuous dialogue between research and clinical environments, and conversion of research findings into clinical settings should be undertaken as swiftly and dynamically as possible without disregard for ethical guidelines. Funding must therefore flow in parallel to basic as well as clinical research.

The following review is an attempt to establish a basic understanding of the existing treatment of spinal cord injuries from accident site to rehabilitation based on the model offered by Ullevål University Hospital and Sunnås Rehabilitation Hospital. My intention is that the review should serve the following functions:

1. Inspire a dialogue about discrepancies between the status quo and the intended model.
2. Provide a foundation against which alternative models or treatment regimes may be compared.
3. Improve understanding of the clinical process thereby enabling scientists to better focus their research at solving specific clinical problems.
4. Guide the accumulation of findings in both research and clinical practice into a “best practice” way of thinking.

Methods

In the process of learning more about the treatment of spinal cord injuries, I have attempted to view the treatment as a chain of distinct phases: 1) pre-hospital treatment, 2) acute hospital treatment involving clinical examination, 3) injury assessment, 4) surgical intervention, 5) post surgery care and 6) rehabilitation.

Information have been gathered through the study of actual cases both real time, by reviewing medical journals as well as through interviewing health care professionals engaged in the various phases.

References are made to representatives from clinical environments along the treatment chain as well as written resources. Frameworks that play a substantial role in some part of the diagnosis or treatment are included as an appendix.

To exemplify various aspects of the treatment chain, some recent case histories have been included in *Appendix I*.

Acute phase- Prehospital treatment

Prioritizing

Upon arrival at the accident site, the injuries are assessed and prioritized by emergency medical personnel according to the basic principles that are directed at saving lives. The following prioritized list drives the focus of the emergency medical personnel:

A-Airway
B-Breathing
C-Circulation
D-Disability
E-Exposure

Traumas resulting in fractures in the vertebral column, including spinal cord lesions and spinal nerve damage are consequently prioritized under D-Disability, and must forego attention when other more acute problems are present. The nature of spinal cord injuries are therefore inherently of such nature that they may be aggravated in the process of attending to more pressing matters. In cases of cervical fractures with phrenic nerve and diaphragm involvement, the injury will be prioritized under A and B, since patients with this kind of cervical injury may require respiratory assistance.¹ It has become common practice to intubate patients who have compromised respiration prior to transportation. The Trauma Manual governs the emergency treatment of patients both prior to arrival and immediately upon arriving at Ullevål. It is a result of several years of learning and involves several types of medical personnel with different specialties. It includes a section on spinal cord injuries and will as such be used as a reference throughout.

Initial Assessment

After excluding problems within the ABC category, or in the absence of such problems, personnel perform a brief neurological assessment including level of consciousness, pupil assessment, and identification of paralysis and paresis. This information is important input for hospital personnel and provides some indication of functions lost, hence driving both initial treatment and rehabilitation. The Glasgow Coma Scale is used to assess the neurological status and possible brain injuries (*Appendix 2*). Moreover, with conscious and coherent patients, EMS personnel may get a better sense of the actual degree of sensory and motor function lost through patient questioning.

Primary vs. secondary injuries

As a rule we can distinguish between primary and secondary injuries. Primary injuries are considered the result of the actual trauma, whereas the secondary injuries are generated by both internal and external factors post trauma. The trauma itself results in cascade mechanisms involving both cellular and non-cellular defense mechanisms. These mechanisms are designed to protect the organism. As is well known, however, our inherent responses are not always perfectly tailored to the task and may also aggravate tissue damage and hence the disability. These internal factors are particularly important to avoid further damage to neural tissue.

Internal mechanisms

As a response to the potential damaging cascade mechanisms, high doses of methylprednisolone have been used in situations where the patient has suffered neural damage. This substance has been thought to provide a neuro-protective effect by limiting lipid peroxidation thereby increasing cellular survival. The criterion for effective treatment has been a treatment onset within 8 hours of the initial injury. The regimen has consisted of 30mg/kg body mass over the course of 15 minutes initially and then 5.4 mg/kg/hour continuously during the following 23hour period.²

The effects of this treatment have been disputed, however, and according to clinical sources significant improvements from this treatment have not been established. The practice of applying methylprednisolone has therefore recently been terminated at Ullevål according to Dr.med Olav Røise and Dr. Josefsen.

External mechanisms

The actual handling of the patient may further aggravate the injury by causing displacements in the injured area. This is especially the case with unstable fractures and dislocations. Proper procedures for securing, lifting and transporting the patients have therefore been adopted.

Collar

All injuries with possible head or neck trauma are immediately fitted with a Stiff Neck collar (Laerdal Pharmaceuticals trademark). This group of patients includes those experiencing paralysis or reporting pain along the column, as well as those being trapped inside wrecks, collapsed buildings etc. It is important to note that all patients who are unconscious should be treated as if having a neck injury and thereby outfitted with a collar.

Log roll

When lifting the injured the guiding principle is to avoid any movement of the column, which is especially unstable for flexion movements. "Log rolling" requires a minimum of 4 people with one person being responsible for the head and neck alone. The head and neck should be kept in a stable position relative to the rest of the body, and the person responsible for the head/neck is also the one guiding the procedure. A slight traction may be applied and will often provide some extent of pain relief. The log rolling procedure should be practiced both with cervical as well as thoracolumbar injuries.

Backboard

Proper harnessing to a backboard is standard procedure when facing a possible thoracic or lumbar injury. Log rolling should be used when moving the injured onto the board. An even safer way is the utilization of a so called "scoop stretcher" which may be applied to the injured person in the actual position in which he or she is found. The scoop stretcher is not a device on which the patient is immobilized and should therefore only be used for transfer and not transport of patients.³

Transportation

With obvious dislocations, the patient should be transported lying on his or her side. The patient may also be transported in a supine position, to avoid unnecessary strain on the column, however, the hips should be kept in a 30degree flexion by padding with pillows under knees and thighs. The Trauma Manual stipulates this practice, however, according to both pre-hospital and emergency room resources, compliance is questionable.

Points for discussion

With respect to the controversial methylprednisolon (MP) treatment, it is noted in the Trauma Manual that even a marginal effect of the treatment may yield substantial practical benefits for the patient.⁴ Still it seems like practice is moving away from this treatment without any immune-suppressing substitute. The use of MP has been widely researched and debated. In 1993 MP treatment was called a two edged sword by Galandiuk et al. Hall and Springer explain this by “the fact that the neuroprotective properties of MP may be offset by the necessary high doses of MP to elicit glucocorticoid receptor-mediated side effects that could comprise the neurological outcome and even the survival of acute SCI patients”.⁵

With respect to transportation it is suggested by trauma specialists that the natural lumbar lordosis may be used more actively in stabilizing the patient and repositioning the fracture in the event of lumbar injuries. Transportation with the patient lying on his stomach would utilize the natural curvature of the spine in an effort to stabilize the column. As this position may seem cumbersome with respect to monitoring the patients’ vital signs, an alternative may be found in applying cushioned but firm support under the lumbar region with the patient lying on his back.⁶

Injuries to joints and the skeletal system are treated according to the principles of *Rest, Ice, Compression, Elevation*, unless surgery is required immediately. The aim is to reduce the inflammatory response of the body, and the use of anti-inflammatory drugs may also be included in the treatment. Limiting the inherent defense mechanisms is considered beneficial both for limiting the injury and for speeding the recovery. One might ask oneself if *RICE* principles may be applied in events of spinal cord injuries more thoroughly than what seems to be the current practice. The use of backboard and collar contribute to *Rest* and to some extent to *Compression*. With the anti-inflammatory effects of methylprednisolon disclaimed and no other drug lining up to replace it, one may question if the anti-inflammatory effects of cooling (Ice) may be utilized in the event of acute spinal cord injuries as in the case of certain brain injuries. Indeed, some institutions are experimenting with induced systemic hypothermia as a means to slow down and impede cellular defense mechanisms launched by the initial trauma.⁷ Locally applied cooling may also be envisioned.

Acute phase-Hospital treatment

The Ullevål-Sunnaas connection

Ullevål University Hospital is covering the acute needs of patients with spinal cord injuries from the entire southern and eastern region of Norway with an estimated population of 2.6 million. It is to serve in conjunction with Sunnås Hospital, a rehabilitation clinic, as a “spinal unit”. The idea is to offer a streamlined, seamless service of acute care and rehabilitation with a minimum of transport and without transfers to intermediate clinics. According to Dr. med. Nils Hjeltne at Sunnaas Hospital, a prolonged post-operative period and transfer to intermediate care facilities hampers functional recovery during the rehabilitation period and is associated with serious frustration and distress for patients.

Arrival in the Emergency Room

There are two main avenues through which patients with acute spinal cord injuries arrive at the ER at Ullevål Hospital:

A. As acute spinal cord injuries (SCIs) are often sustained in conjunction with a multi-trauma event such as traffic accidents where a variety of other medical problems may arise, the patient will be shuttled to the hospital via either ambulance, or, weather permitting via medivac operated by Norsk Luft Ambulanse (NLA). The quickest mode of transportation will be chosen and this depends on a variety of factors such as availability of helicopters in the area, the distance between the helicopter base and the accident site etc. The reporting of a multi-trauma patient will elicit the trauma alarm at Ullevål calling for the deployment of the trauma team. There are several indications for deploying the trauma team at Ullevål, and absorption of high energy is frequently the eliciting factor.⁸ A comprehensive list of criteria for eliciting the trauma alarm is listed in *Appendix 3*.

Upon arriving at the ER, patients are received by a host of specialists who are included in the trauma team according to need. The Ttrauma Manual lists the following resources.⁹

Head of trauma team (resident in surgery)
Senior Anesthesiologist
Resident Anesthesiologist
Thoracic surgeon
Anesthesiology RN (RN=Registered Nurse)
Perioperative RN
Bioengineer
Xray/CT personnel
Emergency room RN

Note: The team lead surgeon may have varying surgical backgrounds, but frequently possesses gastroenterology or orthopedic experience. Furthermore, additional personnel are called upon depending on the type of injuries reported. Current practice thus, exposes a wide range of hospital personnel to acute spinal cord injuries.

Included in the secondary resources are the following specialists:

Neurosurgeon
Facial surgeon
Plastic surgeon
Senior Gastroenterology surgeon
Senior Thoracic surgeon
Senior Orthopedic surgeon
Pediatric surgeon
Radiologist
Senior pediatric anesthesiologist

Needless to say an otherwise stable patient with respect to ABC may not elicit the trauma alarm and deployment of the trauma team. Rather, resources would be deployed in a more prudent manner. The current experience is that emergency medical personnel in the region conduct sound triage leading to a healthy utilization of personnel. For this system to work, however, there will necessarily be some over-triage and according to hospital sources, a closer look at the trauma alarm criteria will be undertaken.

B. In the event of more isolated injuries, or with patients who are stable in terms of respiration and circulation, ABC is less relevant and medical personnel may turn to D for a more brief

neurological evaluation. This assessment is targeted at establishing if the spinal cord is injured resulting in reduced sensory and motor function, and is dependent on an awake and coherent patient. If this patient has an address in the Ullevål Hospital sector (effectively just a part of Oslo), he or she would be admitted there. However, the vast majority of patients are sent to the closest hospital for admittance. The local hospitals provide the full examination of the patient and turn to Ullevål when they encounter neurological findings, or injuries that threaten spinal cord and nerve root function. Through this avenue the patients are reported directly to the neurosurgery department, hence alerting the correct resources. If it turns out that the neurological condition is rapidly deteriorating, the trauma alarm may be elicited within 24 hours after the initial event. High energy exposure is then likely to be the eliciting factor.

Current practice shows that the admittance of patients through this second avenue is somewhat dependent on the experience and knowledge of the EMS personnel. If they assess the patient as likely to have incurred a SCI, they will sometimes turn directly to Ullevål Hospital circumventing the local stop off. Hence, the treatment chain may to some extent be driven by EMS personnel discretion.

In the emergency room the patient is moved from the stretcher to the trauma table with the same guiding principles of log rolling minimizing the risk of aggravating the injury. It is interesting to note that upon transfer, the patient continues to be kept on his back maintaining kyphosis, which does little to alleviate lumbar injuries and may actually aggravate the spinal cord injury. In addition, the hard surface of the backboard and potentially also the trauma table may damage soft tissue if the patient remains in a fixed position for prolonged time periods. Both the Ttrauma Manual and the ATLS (Acute Trauma Life Support) Manual that guide practice at Ullevål Hospital point out that log rolling procedures should be carried out to prevent ulcers and decubitus formation when the patient remains on the backboard for more than 2 hours.

Clinical Examination

All examination should be carried out with the nature of the injury in mind. The initial question that should be answered is whether or not there is spinal cord damage and secondly if the lesion is partial or complete. The focus should be on arm and leg motility. With respect to cervical injuries, retained pin prick-sensibility in lower limbs indicates a partial lesion.

Clinically, it is more important to determine if motion is at all present than the level of power that the patient is able to generate. For example, normal rate and precision for finger movement may indicate good prognosis even though the arm itself may be significantly weakened. Moreover, strength testing may actually dislocate, or further harm an unstable column.¹⁰

A thorough examination will utilize the ASIA scorecard. This model provides a solid foundation that may be used for future reference and follow-up to measure the effects of initial treatment and long term rehabilitation on both motor and sensory function. (*Appendix 4*) The alignment of the spine is examined while the patient is log rolled to identify dislocations, protrusions etc. It is very important to assess both sphincter tonus and bladder function upon arrival as well as during continuous monitoring of the patient. The ATLS manual provides a comprehensive list of items for assessment and management in the case of spinal cord injuries. (*Appendix 5*)

The current practice at the Ullevål University Hospital divides the responsibility for spinal injuries between neurosurgeons and orthopedic surgeons. Furthermore, any patient with an injury producing neurological symptoms including sensory and motor deficits of some degree will be cared for by a neurosurgeon in the proper facilities. Other injuries may have damaged skeletal and ligament structures without affecting neural tissue to the extent of producing symptoms. Patients with the latter form of injuries are cared for by the orthopedic surgeons. According to Dr. Josefsen, a neurosurgeon at Ullevål, all cervical injuries regardless of ASIA score will require the attention of the Department of Neurosurgery. Furthermore, he points out that neurosurgeons and orthopedic surgeons sometimes operate side by side at Ullevål.

As noted, the multi-trauma patient is often intubated and remains sedated while being examined. The neurological assessment in such situations therefore depends on findings at the accident site prior to intubation. The investigations of EMS personnel can be summarized in an initial Glasgow Coma Score, observed movement of extremities as well as other findings indicating presence and level of spinal cord damage.

Diagnostics

Spinal cord injuries typically exist as isolated injuries to the cervical, thoracic, lumbar and sacral region. However, as mentioned earlier, such injuries often coincide with other medical problems such as fractures to extremities and, damage to internal organs causing internal bleeding with circulatory and respiratory implications. The patient may also be unconscious from a head trauma.

In the event of a multi-traumatized patient who is unconscious or in any other way incoherent and where spinal cord injuries are possible, diagnosis scanning is carried out according to a specific regimen.¹¹

Cervical injury

X-ray of the cervical column with side projection is taken only if the patient has been exposed to an event with high risk for sustaining a cervical injury. In addition, CT scanning is performed of the entire cervical spine. CT cerebral, chest and pelvis are also included in a CT trauma series. "High risk" events include the following criteria and coincide with the description for injuries ensuing from high energy absorption.

- Falling from > 5meters(15 ft.)
- Traffic accident with speed at collision > 50 km/h (35 miles/h)
- Collision causing death
- Severe head injury defined either clinically or radiologically
- Symptoms indicating neck injury
- Pelvic fractures or multiple extremity fractures

At Ullevål Hospital the trauma room has x-ray and the analysis of the pictures is carried out continuously while the patient is being stabilized in terms of ABC. The CT room is located across the hallway from the trauma room. The trauma manual points out that CT should not be performed on circulatory unstable patients, but rather postponed until the patient is hemodynamically stable.

In the event that the criteria above are not satisfied, the incident is classified as "low risk" for neck injury and consequently x-ray is the most prominent diagnostic tool. In this case all 5 projections are taken and a more targeted CT scan is only carried out if any of the x-rays show positive findings.

Thoracic, lumbar and sacral injuries

With injuries in other segments of the spine, CT scanning is favored over conventional x-ray. CT scanning requires a circulatory stable patient, and in the event of unstable patients, X-ray is taken with anterior-posterior (A-P) and lateral projections of the thoraco-lumbar-sacral column. If any of these scans are positive, CT scans are taken as soon as the patient is stable. If other injuries in the thorax, abdomen and pelvic regions require CT scanning, these scans may be reformatted and used for assessing injuries to the spine. To assess the extent of the injury it is important that CT scans include the entire corpus vertebrae both above and below the fracture.

With more isolated spinal cord injuries, one may direct x-ray and CT more accurately based on neurological findings. Orthopedic surgeon Dr. med. Olav Røise has indicated that x-ray as a diagnostic tool is in the process of being terminated in favor of CT scanning alone. The advantage of this change is cost and time efficiency. There may be a drawback, however, as according to Dr. Røise the tracking and follow up of the injury and patient using subsequent x-ray examination is strongly impeded without an initial x-ray.¹² Dr. Josefsen does not share this concern and notes that follow-up CT scans are taken at monthly intervals post surgery to determine status. CT imaging is of superior quality compared to conventional x-ray scans. Røise's concern may be rooted in the fact that follow up x-ray scanning is readily accessible at Sunnås, whereas CT scans would entail transportation back to Ullevål. Another point he makes is that the superior quality of CT scans must be weighed against a significant increase in the radiation load.

As the use of x-ray is being terminated, MRI is becoming increasingly important as a tool for the neurosurgeons to compliment CT. This allows determination of the status of soft tissue such as ligaments and inter-vertebral discs, as well as discovering spinal hematomas etc. Another advantage of this modality is the absence of potential harmful radiation. *Appendix 6* summarizes the pros and cons of the most common diagnostic modalities.

Evaluation

Neuro-surgeons or orthopedic surgeons assess the X-ray and CT scans depending on the location of the injury and neurological status. Among the orthopedic surgeons at Ullevål, some have particular interest and experience in analyzing radiological diagnostics on the basis of injury mechanisms and accident site findings. This tradition makes some of the experienced trauma surgeons particularly well equipped in conducting this evaluation. There does not seem to be a similar tradition within the Department of Neurosurgery.

In practice, the pertinent members of the trauma team will venture into the CT room and participate in the analysis while the anesthesiologist and RN monitor the patient in the CT tube. The neurosurgeon will closely consider the head and spine scans. Indeed, during the daytime specialized neuro-radiologists are available to be consulted to ascertain findings that may have been overlooked during the night. There is also a specific neuro-CT unit, albeit in a different location at Ullevål. In the event of MRI being required to scan the spinal cord for hematomas etc. the patient must be moved to another floor. Moreover, MR personnel are not on duty 24 hours, but may be called on if required.

The ATLS manual used for specialized training of doctors in handling trauma situations provides a comprehensive checklist for x-ray identification of spinal injuries including both anatomical assessment and guidelines for detecting abnormalities.¹³ (*Appendix 7*)

Classification and treatment

The classification of injuries to the spine is complex. It was briefly mentioned that based on the division of labor between orthopedic surgeons and neurosurgeons, injuries may be divided into the following groups.

1. No neurological deficits
 - a. Thoracic
 - b. Cervical
 - c. Lumbar
2. Neurological deficits
 - a. Thoracic
 - b. Cervical
 - c. Lumbar

The orthopedic surgeons will essentially cover 1a and c including injuries to lower segments of the column. This group may be further divided into sub-groups based on x-ray/CT findings of fracture, dislocations etc. or no such findings. Furthermore, another key question is whether the injury is stable or unstable and requires surgery. Absence of instability does not rule out surgery and there are several other considerations that must be made. Including the degree of deformation, whether the axis is in alignment and to what extent there is a compression of vertebral bodies.

Several different assessment schemes have been proposed with the goal of accurately assessing which injuries will require surgery and which may be treated conservatively. The question of stability of the spine is pivotal in this respect; a useful definition of stability is “the ability to withstand stress without progressive deformity”.¹⁴ Denis proposed a scheme in 1983, according to which the spine is divided into three separate columns and instability is defined by the compromise of more than one of these columns.¹⁵ The ABC scheme was introduced by Magerl, Aebi, Gertzbein, Harms and Nazarian in 1994, and is based on a two column system.¹⁶ Both schemes are summarized in *Appendix 8* and contribute to the current guidelines for operative treatment of thoracolumbar injuries at Ullevål hospital.¹⁷

- Neurological damage
- Affection of at least two columns (according to Denis)
- Kyphosis >15 degrees
- Height reduction of anterior vertebral body >50%
- Most B fractures (according to Magerl et al.) flexion-distraction injuries
- All C fractures (according to Magerl et al.) luxation, rotation and shearing injuries

According to Dr. Røise, head of Orthopedic Center at Ullevål, these criteria are in the process of yielding a new classification system that scores injuries on the basis of the injury mechanism, and/or pathomorphology of the injury, the status of the posterior longitudinal ligament and the neurological status of the patient. The Thoracolumbar Injury Severity Score (TLISS) proposed by Alexander R. Vacaro et al. (2006) is the first classification scheme to include neurological status in the assessment. It has been tested and found reliable, although it was pointed out that pathomorphology was a better predictor than injury mechanism. The

adaptation has been named the Thoracolumbar Classification and Severity Score.¹⁸ Both the original TLISS and the TLICS have been included in *Appendix 9*.

Dr. Røise suggests that treatment in the past has been too conservative and that failure to operate has resulted in patients with skeletal and muscular problems in the long run.¹⁹ The adoption of the TLISS may provide a more structured approach to the decision of conservative versus operative treatment.

As a guiding principle, injuries without neurological deficits but requiring surgery are operated as soon as possible to limit or avoid the accumulation of secondary injuries and the onset of neurological symptoms. Furthermore, all operative procedures should aim to maximize the possible range of motion and mobilization of the patient, which is essential for maintaining and improving functions.

The neuro-surgeons will be in charge of groups 1b and 2. The stability of the injury here is also important for the selection of treatment options. According to the current trauma manual, few cervical fractures are operated on immediately, but most of them within 2-3 days. The most prominent indicator for surgery is a partial lesion and a patient with deteriorating neurological status. Furthermore, dislocations and reduced spinal cord space may also require rapid surgery. Soft tissue injuries inflicted on structures such as ligaments and discs should also be considered. Complete lesions rarely show improved function as a result of surgery, but they are also operated to assure swift mobilization of the patient. According to Dr. Josefsen, a situation with improving neurological status should warrant a more apprehensive approach and one will often wait and see regardless of the nature of the injury.²⁰

To complete the complex picture of assessing these injuries, 10% of injuries to the vertebral column have at least one associated, non-consecutive vertebral injury. That is, there are fractures/injuries at multiple vertebral levels. (*ref. Patient histories # 2 and 3*). Hence, neurological deficiencies may arise from various abnormalities and singling out which to treat surgically and which to approach conservatively is a challenge.

Various surgical methods are used, and there is a constant revision of these as well as the associated hardware based on new findings. Current methods being utilized:

Cervical

1. Posterior fixation with cerclage and bone transplantation, or Cervifix system including cranio-cervical fixation.
2. Anterior fixation with cervical spine locking plate (CSLP) alone or combined with removal of spinal cord impeding fragment.²¹

Thoraco-lumbar

1. Universal Spine System (USS)- Sacral to Th-6
2. Axxess – From Th-6 to C7²¹

The objectives of the operation with respect to cervical as well as thoracic and lumbar injuries are to,

- Optimize spinal cord functioning and space
- Reposition the fracture faces to achieve sound axes
- Fixate the fracture to produce long term stability²²

The Trauma Manual stipulates the use of conservative (non-operative) treatment in situations in which the fracture is “adequately stable” according to the orthopedic classification.²³ This is especially applicable to cervical injuries that in the absence of cord injury, reduced space and broken ventral axis, may be treated conservatively with a collar. Camp round collar or the Miami Collar has been specified for this purpose depending on the rigidity required. The Miami Collar offers firmer, more rigid support.

Pre surgery

Patients awaiting surgery are admitted to post-operative or intensive care facilities- As noted, however, - patients with deteriorating neurological status may be operated as emergency care. Scheduling the patient for surgery and management of resources for the OR (operating room) appears to be handled in such a way that the patients who do not necessarily require immediate surgery are scheduled to assure the availability of the most qualified set of resources in the OR. As noted this often entails combining neurosurgical - and orthopedic surgical competencies.

Before surgery, CTs and MRIs are reviewed thoroughly by the operating team. It is also emphasized that patients should be extubated and awake, hence coherent enough to allow for a neurological evaluation establishing sensory and motor function prior to invasive treatment.

Post surgery

After the surgery, the patients are taken back into the post-operative or intensive care unit depending on their overall status. Depending on the result of surgery and a full neurological review, the patient will either be prepared for the spinal care unit at Sunnås, or transferred to a local hospital. The philosophy of the spinal unit of Ullevål/Sunnås is a swift transfer of the patient to a definite care facility where comprehensive rehabilitation may proceed without unnecessary delays. Upon recovery from surgery the patients are transferred from Ullevål. Patients with neurological deficits are transferred to Sunnås Hospital provided that there are vacancies in their spinal injury ward. According to chief physician Dr. Nils Hjeltne, patients must rarely wait for beds, but admission to Sunnås is contingent on healthy respiratory status, and the hospital cannot accommodate respirator-dependent patients. Dr. Hjeltne admits that competence in handling patients with respiratory difficulties is lacking at Sunnås. From a recent count of 100 patients admitted to Ullevål Hospital with cervical injuries, 45 underwent a swift transfer to Sunnås whereas 40 were transferred to intermediate care facilities with respiratory problems stated as the primary reason. The remaining 15 died upon arrival at Ullevål.²⁴

According to Dr. Hjeltne, funds were once allocated specifically to assure round-the-clock post-surgical care at Ullevål specialized to the needs of patients with spinal cord injuries. It is felt that 4-5 post-operative beds should be designated for this purpose. This practice has not been functioning entirely as intended. Whereas Dr. Hjeltne reviews patients at Ullevål for transfer to Sunnås weekly, the designated beds and specialized care at Ullevål have not been provided. Ullevål Hospital is large and budgetary considerations may be at fault in this regard. Nevertheless, the intended philosophy was to ensure that ample resources for maintaining respiratory and circulatory functions should be coupled with specific rehabilitation competence and clustered around this intermediate care unit. Moreover, Dr. Josefsen would like to see a 24- hour-a-day comprehensive service with specialized nursing, physical therapy and other medical services. The intention would be to facilitate a maximally beneficial and

swift post-operative period of 3-5 days prior to transfer and to avoid secondary hospital stays. Such a facility would provide the necessary bridge between the emergency care specialty of Ullevål and the rehabilitation competence at Sunnås.

Dr. Hjeltne admits to lacking upstream competence on respiratory assistance, but he does receive part-time assistance from an anesthesiologist to alleviate sub-acute problems. When asked about what he would change upstream, Dr. Hjeltne points to reestablishing the intended intermediate spinal care unit at Ullevål.

The patients who have not sustained neurological deficits are transferred to their local hospital for proper care once they have recovered from surgery.

Rehabilitation

Organization

At Sunnås Hospital patients are admitted to the RMM (Ryggmarg og Multitraume) ward. This ward is the result of a merger of the spinal cord and multi trauma units. There are 56 beds in the RMM ward. This section houses the primary patients at Sunnås, which is situated on the scenic Nesodden peninsula outside of Oslo. Typically the patient population includes patients with spinal cord lesions and neurological deficits, multiple fractures of the extremities or both. A common denominator is the need for complex rehabilitation services requiring cross-professional cooperation. A criterion for admittance is stability with respect to circulation and respiration. In addition to the spinal cord/multi trauma unit there are separate staffed units for head trauma and stroke patients. Sunnås covers the rehabilitation needs of patients from southern and eastern Norway. Frequently other regions apply for beds when their capacity is exhausted.

According to regional health care administrators the incidence of spinal cord injuries is approximately 20 per.1 million people. This makes for about 70-90 new patients per. year. Sunnås accommodates close to 50% of these patients.

The duration of the average stay for the RMM patients is 3 months. According to Dr. Hjeltne this is a result of regulatory measures governing allocation of rehabilitation funds. This does not mean that patients are discharged regardless of their medical status after 3 months. However, at this point patients often have to be readmitted for a second rehabilitation stay for which funds are re-allocated. Some claim that this is a cumbersome and rigid procedure, but another view is that this practice actually provides the incentives for a focused and progressive rehabilitation process. According to one team coordinator, the risk of falling into a mode of complacency is no longer an option. Both the patients and the staff need to keep their eyes on the ball, and the ball is getting the patients as far as physically possible and a little further. The aim, of course, is for the patients eventually to be able to move home and to resume their domestic and occupational roles. In a sense, therefore, an economically driven policy may render some clinical relevance. In addition, it should be noted that shortened rehabilitation stays should increasingly force local governments to accept responsibility and focus local resources on the reintegrating the patient in the local community, and not view Sunnås as a “long term” solution for patients.

The RMM admittance group reviews applications weekly and regional applicants are a priority compared to patients from other regions. Currently Sunnås is operating with

vacancies that warrant taking in patients from central and northern Norway. Once an application is accepted, one of the teams is notified and communication between Sunnås and the primary hospital, most often Ullevål, secures the exchange of all pertinent medical information prior to patient transfer. The chief physician at Sunnås, Dr. Hjeltnes, is at Ullevål weekly to review prospective patients.

Sunnås approaches rehabilitation with multifunctional, multi-professional teams. Teams #1 and #2 have identical compositions and consist of two doctors, several nurses, physical and occupational therapists, as well as psychologists. Social services and teachers are also involved in the process. These two teams are in charge of all the patients in the RMM unit.

Arrival

Upon arrival, the patient is attended to by a nurse from the team to which the patient has been assigned. Furthermore, the team doctor will conduct a physical examination, and a rehabilitation plan will be outlined. Whereas the team caring for the patient will convene the following day, a reference to all new patients within the past 24 hours is made at the doctors' morning session. The patient team constructs a detailed time schedule for the patient who is thought to benefit from a structured approach.

The arrival at Sunnås can be associated with significant stress for the patients. In addition to the fact that change may inherently be perceived as stressful, the patients find themselves in a situation in which a life-threatening injury has been avoided, and they have to become increasingly aware of the possibility of facing a lifelong disability. Many of them are transferred directly from the intensive care unit and have only been awake for a few days since surgery. To provide some relief in this process, psychologists are readily accessible and actually make a point in visiting the patient to assess his or her needs during the first 24 hours at Sunnås.

It may sound as if the rehabilitation stay is a rigorous process with a strict schedule and time constraints. As much as the process is geared towards producing achievements in only a few months, the staff fully acknowledges that introduction to a new reality takes time. Patients are often granted a few weeks before they are guided into a more conscious rehabilitation mode. It is most certain that there are significant individual differences both in terms of personality and type of injury. Hence, initiation and progression require an individualized approach.

The 3 phases

The rehabilitation process can be divided roughly into 3 phases with the following themes defining the different phases:

Phase 1: Reestablish natural functions and maintenance of health.

Phase 2: Active rehabilitation, participation and transfer of ownership.

Phase 3: Preparation for moving home and life ahead.

Well into phase 1, after a few weeks of training and letting the patient adjust and come to terms with training regimes etc., a team meeting is conducted with the relevant professions present. During this meeting the various team members report on training and progress, and goals within various fields are worked out with the patient. The meeting is in the form of a round table discussion with the patient in the center. Team members speak in turn, addressing the patient in person. The meeting is directed at achieving consensus and "buy in" from the

patient with respect to areas of emphasis and realistic, productive goals. A process of constant “plan and review” then governs the work forward with the patient to gradually bring him or her closer to recovery. An initial meeting between a patient with a cervical injury and his rehabilitation team may include the following tasks and goals:

Physical therapy:

Improve respiratory function

Increase incline of bed gradually from horizontal to vertical

Strengthen neck to be able to terminate cervical collar treatment

Initiate pool exercises

Nursing:

Be able to take care of personal hygiene, brushing teeth, washing face etc.

Restroom training, shower training etc.

Prevention of ulceration and pressure wounds

Occupational Therapy:

Construction and adaptation of devices for facilitating eating and drinking

Initiate contact with the local occupational therapist services that in turn will facilitate the process with local government and assess the need for domestic alterations

Planning leave of absence to visit home once family and extended network is ready

Social services:

Facilitate contact with school authorities to facilitate adjustments to course load or education plan.

Although few breakthroughs occur during these initial meetings, the thought is to prepare the patient for a little more focused approach to rehabilitation. Furthermore, establishing realistic goals and signaling commitment from the staff is likely to motivate and help bring the patient up to speed and to some extent transfer part of the ownership of the process back to the patient who should become increasingly able to focus his or her energy.

Phase 2 of rehabilitation involves moving forward with the same attention to planning and reviewing goals.

Towards the end of the stay, the patient is prepared for leaving. The progress is reviewed and standard tests are performed to assess the status of the lower gastro-intestinal tract as well as urinary tract function. Included are cystometric evaluation, creatinine clearance as well as a number of blood samples. All formalities with respect to local authorities are reviewed including aid packages to cover home assistance, transportation etc. Further physical therapy is often needed and this is also arranged for at this time.

During their stays at Sunnås, the patients receive on-site follow up consultation by both orthopedic surgeons and neurosurgeons. Radiology personnel arrive weekly to take x-ray scans for these consultations. The orthopedic surgeon and neurosurgeon each spend a day every month reviewing how the healing is progressing, to what extent the patient may increase the level of activity and how they should be taken care of if fractures require attention after the patients are discharged from Sunnås.

Whereas some patients may go directly home, Sunnås is also transferring patients to secondary and more local rehabilitation clinics. Regardless, upon discharge the patients have sometimes already made plans for a secondary stay at Sunnås, which is geared towards assessing specific problems that may have surfaced after a period of approximately 6 months at home. The duration of the secondary stay is approximately 5 days. The secondary stay involves the same professions. However, Team#3 is responsible for the secondary stay patients, who are accommodated in a separate section at Sunnås Hospital.

Summary and findings

The intended model

The philosophy of streamlining has been driving the treatment chain of SCIs from the time of the accident to the discharge from the primary rehabilitation stay. The model offered by the Ullevål-Sunnås connection utilizes two distinct facilities. An advantage with this model is a definite separation of modes between emergency care and rehabilitation. The challenge, however, is to manage the necessary communication between the two as well as providing sufficient and suitable treatment during the period of post operative care prior to the time the patient is well enough for rehabilitation.

Apparently, funds were allocated in 1992 to both Sunnås and Ullevål to complete the concept of a seamless spinal unit with designated SCI post operative-beds. There has, however, been a shortfall compared to the intention and patients are still, 14 years later, pressed out of the ICU too early to effectively enter into rehabilitation. This solution can be both inferior in terms of the recovery of function, and frustrating for both the patients and their families. Another issue is that it probably is inefficient and, wasteful, with respect to societal resources. This argument is based on the assumption that resource usage that is tailored to specific needs provides the most efficient solution.

The ICU beds have a 2:1 or 1:1 nurse/patient ratio and are very expensive to operate. Therefore, patients should vacate these beds as soon as they no longer require this level of care. As the situation is now, they may actually be kept there longer than necessary from an acute monitoring point of view, yet moved too soon to enter into an efficient rehabilitation mode. Hence, the practice is both inefficient resource-wise and inappropriate treatment-wise. If the patient is moved to Sunnås prematurely, the patient may not receive the care he or she requires- (*ref. Patient history #1*). Furthermore, if the patient is transferred to a local ICU he or she will not receive the required care and will also confiscate resources that are applied in a sub-optimal way and could have been used more appropriately for other needs.

The heart surgery unit at Ullevål delivers patients to an intensive care unit as does the department of neurosurgery. In the past, patients that had recently undergone heart surgery were transferred out of a 1:1 or 2:1 nurse/patient environment straight into the normal heart ward. Needless to say this transfer was a giant leap for patients with major circulatory issues and mortality rates also ran high. After a significant struggle, a “step down unit” was designed to cater specifically to the post-operative needs of heart surgery patients with a more moderate nurse/patient ratio. According to cardiothoracic surgeon Dr. med. Knut Kvernebo, this was a tremendous step forward, reducing post-operative mortality and relieving the load of both the intensive care unit and the normal mainstay heart ward.

A report released last year by a working group of former patients and health care professionals involved in the treatment of SCIs, claims that an optimal treatment chain for SCI includes an intermediary unit of three beds specifically staffed for the needs of such patients.²⁵ Furthermore, with vacancies, the beds could be used for elective surgery, which is frequently needed by patients in the rehabilitation phase of the treatment chain. The best location for this unit would probably be in close proximity to the ICU at Ullevål. The lack of these specialized post-operative beds constitutes a discrepancy compared with the intended model. The removal of the discrepancy will require both sufficient funding, and a sensible model for managing the unit. The report is in line with the opinion of Dr. Hjeltne, chief physician at Sunnås.

According to trauma room officials, the handling of patients by EMS personnel is both efficient and sound from a medical perspective. Routines appear to be well designed and compliance to regulations appears to be good. One exception may be the specification of transportation with a flexion of 30 degree in the hips in the case thoracolumbar injuries. This procedure is suggested by the Trauma Manual, but sources claim the method is not being used routinely. Table 1 summarizes the discrepancies between the status quo and the intended model.

Table 1 Discrepancies between status quo and intended model

Gap	Source	How to bridge it
Lack of a 3 bed (min.) intermediate care unit with facilities and staff tailored specifically to patients with acute spinal cord injuries	Dr.Hjeltne,	Allocate resources, locate facilities, profile and competence of staff, re-organize, hire/transfer personnel, manage, review.
No routine transportation of thoracolumbar patients with 30 degree hip flexion	Pre hospital staff, Emergency room staff	Emphasize logic, training of personnel

New ideas

Transportation

According to Dr. Røise, a possible modification to the current transportation regime would be the introduction of firm lordosis support as an early measure to use the natural spine curvature as a method of repositioning critical structures. Furthermore, early use of ice and hypothermia treatment as a method of reducing inflammation, hematomas etc. has not been explored so far.

With respect to the transportation regime one might investigate the possibility of clinical trials once a suitable hardware solution has been developed.

Acute treatment

With respect to the induction of hypothermia, it would be interesting to assess the status of current research and determine in what direction it is heading. Another point is to look at possible ways to introduce anti-inflammatory measures with more localized cooling. This could potentially be done in conjunction with the development of the above-mentioned lordosis support.

Table 2 Possible changes

Change	Source	How to explore?
Improve transportation methods and introduction of adjustable lordosis support	Dr.Røise	Investigate possible product alterations or adjustments, as well as new designs. Requires both resources and design input.
Develop new means to battle inflammatory reactions post trauma		Research both systemic hypothermic treatment, localized cooling as well as possible new drug regimens

Rehabilitation

The report “Utviklingen av rehabiliteringstjenesten i Helse Øst” (Development of rehabilitation services in Health East region) of last year conveys several ideas for improvements to the current model. The rehabilitation phase itself should according to the report be subjected to an alternative financing solution that would allow patients to stay longer at Sunnås. The report indicates an average required duration of rehabilitation of 10-30 weeks, which is significantly longer than the current financing model permits. Furthermore, patients and employees have been voicing concerns about resource cut-backs along the entire rehabilitation chain.

In any instance with resources being cut back, this may lead to lower functional levels of discharged patients. The primary rehabilitation stay is progressive in the sense that it should aim to take the patients to a level where they may be able to move home. This may be within reach in some cases and an almost impossible task in other. The report mentions situations in which the patient has failed to acquire essential skills before discharge. Whether this is a result of poor coordination, physical disabilities or a lack of resources is unclear. To assure that the necessary skills are acquired, a “need to achieve” checklist may have to be developed for each patient.

Several patient groups with SCIs may for various reasons be less able to participate in the rehabilitation effort, hence necessitating additional kinds of health care services. These groups include elderly without motivation or ability to recover, mentally ill, patients with extensive substance abuse, and children. The thought is that these patients may better be taken care of by other institutions, as long as these alternative institutions cooperate with Sunnås and receive proper training and assistance, tailoring the therapy to the specific patient.

A need has also been expressed for a more extensive use of an outpatient clinic at Sunnås. Another suggestion is to utilize ambulant rehabilitation teams visiting the patients on their own turf, thereby getting a better idea of what they are struggling with in day-to-day living.

Lastly, it has been suggested that alternative rehabilitation facilities could be used when a patient’s condition no longer warrants the competence of Sunnås and other institutions could meet further rehabilitation requirements.

The report “Utviklingen av rehabiliteringstjenesten i Helse Øst” suggests that undertaking the aforementioned measures may reduce the required number of beds for primary stays at Sunnås and yield an optimization of resource usage.

Table 3 includes some of the proposals made by the working group that would improve on the existing model.

Table 3 Improvements to existing model

Improvement	Source	How to achieve?
Alter financing model to allow for longer primary rehabilitation stays	”Utvikling av Rehabiliteringstjenesten I Helse Øst”	Requires decision on administrative level
Utilizing partner institutions to a larger extent	”Utvikling av Rehabiliteringstjenesten I Helse Øst”	Institutional decision at Sunnås, education, re-organization
Further develop outpatient service at Sunnås	”Utvikling av Rehabiliteringstjenesten I Helse Øst”	Resources or reallocation, staffing and organization
Develop ambulant rehabilitation team	”Utvikling av Rehabiliteringstjenesten I Helse Øst”	Resources or reallocation, staffing and organization
Generate list of “need to achieve” prior to discharge		Build into rehabilitation team/patient meetings

Coordination

A patient with a SCI will require attention from several institutions both within and outside the health sector. This attention will sometimes involve a lifelong commitment. The cooperation between the various actors requires an improved and more centrally located coordination, which should be carried out by the regional health care administrator, Helse Øst. This coordination will facilitate the transition to normal life after going through primary rehabilitation. The aforementioned report would also like to see a more rapid induction of local resources from the community to which the patient belongs. The speed with which these local resources are made effective varies a great deal, and in some cases the patients and their families must battle for the proper attention. The report concludes that a safety network should be in place and validated prior to each individual patient’s discharge.

Another aspect of coordination exists in the sense that patients will need information and guidance long after their primary stay at Sunnås. Some will venture back for secondary stays and some may utilize the outpatient service. Others may want to inquire about alternative treatment regimes if their physical improvement and recovery of function come to a grinding halt. Sunnås is the most likely source of information and should be able to guide patients and ex-patients towards possible and sensible alternative treatments within ethical boundaries. This requires a tremendous effort by the staff in terms of time, energy and money, and entails staying abreast of developments in numerous fields of research and clinical environments.

Statistical Remarks

The magnitude of spinal cord injuries as a medical problem is significant. Within the EU member countries more than 330,000 people currently have some degree of disability from a spinal cord injury. Furthermore, 11,000 new people enter the pool each year.²⁶ In Norway the prevalence is about 5,000 and the incidence about 100. The leading cause of the injury in most of the industrialized world is motor vehicle accidents giving rise to approximately 50% of cases.²⁷

Traditionally the typical spinal cord injury patient has been young with an average age of 28.7 years. Within the past 20 years and with an increasingly older general population, the average age has increased to about 38 years. Another contributing factor may be the tendency of increasing activity levels among more mature individuals as well as the general increase in traffic and the risk of accidents.

Despite the increasing age of the typical spinal cord injured patient, the life expectancy is increasing due to general improvements in health as well as particular advances in health areas related to spinal cord injuries. Leading causes of death have been renal failure, pneumonias, pulmonary embolisms and septicaemia, and improvements in treatment regimens for these conditions have improved on both quality and expectancy of life. A key factor is still the level of injury. Table 4 summarizes life expectancy for different injury levels.²⁸

Table 4 Number of years in addition to age at time of injury

Age at time of injury	No spinal cord injury	Incomplete injury at any level	Paraplegic	Low tetraplegic	High tetraplegic	Ventilation assistance required
20	58.4	53.3	46.3	41.7	37.9	23.3
40	39.5	34.8	28.6	24.7	21.6	11.1
60	22.2	18.3	13.5	10.8	8.8	3.1

Based on figures from the Spinal Cord Injury Statistical Center, incomplete tetraplegia has been the most common injury and the prevalence is rising while prevalence of both complete paraplegia and tetraplegia are declining. Table 5 shows the prevalence of the various injuries.²⁹

Table 5 Injury Level and Prevalence

Level of injury	Incomplete Paraplegia	Complete Paraplegia	Incomplete Tetraplegia	Complete Tetraplegia
Prevalence (%)	18.5	23.0	34.1	18.3

The different injury levels entail very different disabilities and hence injury level determines the level of care and is a key factor driving the cost of treatment. Based on historical data, cost figures for treating patients with the respective injuries are shown in Table 6.³⁰

Table 6. Cost Figures (USD)

Level of injury	Incomplete Injury any level	Paraplegia	Low Tetraplegia	High Tetraplegia
Cost first year of treatment	218,504	270,913	478,782	741,425
Cost each subsequent year	15,313	27,568	54,400	132,807

Norway Example

Based on the figures above, an interesting exercise would be to estimate what one year of spinal cord injuries would cost in terms of future health care and associated needs.

100 new spinal cord injury patients enter the pool in Norway each year. The average age at the time of injury as noted above is approximately 38 years. Based on the statistical distribution of injury levels, the life expectancies associated with each patient group, and the associated cost figures, we can calculate the estimated total cost:

Injury Level	Number of Patients	Life Expectancy	Total Cost first year (USD)	Total Cost Subsequent years (USD)	Lifetime cost for group (USD)
Incomplete Injury Any Level	53	35	11,500,000	27,500,000	39,000,000
Paraplegic	23	29	6,200,000	17,700,000	23,900,000
Low Tetraplegic	9	25	4,900,000	11,700,000	16,600,000
High Tetraplegic	9	22	6,600,000	25,100,000	31,700,000

Note: To simplify the calculations on which the above figures are based, I have used 40 years as the age at time of injury instead of the average 38 years. Furthermore, I have divided the estimated predicted number of complete tetraplegia patient equally between high and low level tetraplegias.

Conclusion

Based on the cost figures provided by the Spinal Cord Injury Statistical Center, the current spinal cord injury rate increases the future economic burden of Norway by more than USD 100 million, or approximately NOK 500 to 700 million, annually. Most of this is likely to end up as liabilities of the health care system.

One may certainly challenge the validity of US historical cost estimates for the Norwegian health care system. Nevertheless, it seems quite certain that the cost of spinal cord injuries is

by any measure significant. Considering the notion that early rehabilitation efforts are likely to have better yields than later efforts and the fact that a streamlined treatment chain is likely to bring about the best physical result for the patient regardless of injury level, one may suggest that substantial financial investments in facilities, knowledge and staff are justified.

Therefore, efforts mentioned earlier to allow longer primary stays as well as initiatives to facilitate a more tailored early rehabilitation should be undertaken with sound economic and medical justification.

Appendices

Appendix 1

Patient history # 1

Day 0-AM

A farmer is struck in the head by a ball of hay with approximate weight 500 kg. while operating a forklift. He is immediately paralyzed from the chest down and reports severe cervical pain. Local EMS personnel apply a cervical collar on arrival and immobilize the head. The medivac (NLA) arrives with an anesthesiologist after 40 minutes. The farmer is extracted from the forklift by being slid onto-, and secured to the backboard. The patient has stable respiration and circulation. He receives 5mg Morfin and 10 mg Afipran prior to air transportation. The patient is reported to be healthy prior to the incident.

Upon arrival in the ER at Ullevål hospital the patient is reported to be stable, awake, coherent and oriented with GCS of 15. He reports pain in cervical/shoulder region. There is no visible dislocation. The collar remains on. There is visible motion in upper but not lower extremities. The vital signs are within normal limits. There is no visible sign of external injury or dislocation. The right shoulder is in normal position. The pain is likely radiating from neck. The sensory function is intact above, but not distal to the mamilla.

Chest and pelvic x-ray are negative. FAST is negative.

Trauma CT is taken. CT caput neg. CT column shows dislocation injury of C6. Kominutt fracture corresponding to left foramina transversus with intermediary fragment.

CT angiography is requested to exclude injury to the vertebral artery. A cervical MRI is requested by neurosurgeons prior to applying traction.

Description of operative procedure and assessment by neurosurgeon:

There is sensory deficit corresponding to Th2. There is C5 motor function bilaterally, but somewhat better on the right side (4+ vs 4). CT shows dislocation of C6/C7. Fracture through left side facet joint. The CT angiography is negative for vertebral artery injury. MRI is negative for hematomas. Traction is indicated. The patient is transferred to PO for observation.

Traction is applied using 20 ml Xylocain and 1 % Adrenalin. 2.5 kg. weight is applied in the length of the column with light flexion. New CT scans will be made in the morning prior to possible surgical intervention.

Neurosurgeon examination notes:

There is paralysis in both legs. Sensory function: There is sensory loss from Th1 and down on thorax as well as partial loss for C6 and C7 distally to elbow. No sensory function in C8.

Motor function: The patient can move his shoulders, flex and extend in elbows and has retained some wrist movements. He has no finger motility. Cranial nerve status is reported normal. CT shows forward complete dislocation of C6 on C7. Kominutt fracture corresponding to left foramina transversus with intermediary fragment. The family has been informed. Traction has been applied.

Day 1

Anesthesiologist notes:

C6/C7 injury described previously. Scheduled for operation after CT today.

CNS: The patient is awake, coherent, with sensory deficit from mamilla bilaterally. Flexion function of arms bilaterally intact.

Respiration: Good ventilation and oxygenation with some O2 supplement. Start up of respiratory PT. Circulation: Some Noradrenalin support to keep MAP at or above 85.

GI/nutrition: fasting for operation, CVK entered and parental nutrition started.

Description of operative procedure:

There is a cervical injury of C6-C7 with disc fracture, complete facet joint dislocation and spinal cord injury and the following procedures are conducted;

Open repositioning of cervical fracture

Posterior fixation with 2 Atlas cables between C6 and C7.

The surgery is carried out with the patient facing down with traction of 3.5 kg which is removed after surgery. The patient is then log rolled onto his back for;

Anterior fixation and with Cervical Spine Locking Plate 22mm from C6 to C7

Auto transplantation from right hip to cervical column

The ruptured disc is removed and replaced with tricortical bone transplant from the hip. The CSLP is fitted and attached with screws to corpus C6 and C7.

Prophylactic treatment with antibiotics is initiated.

Day 2

CT control indicates that the patient can be mobilized freely. Klexan treatment is initiated.

Neurosurgeons report the patient is ready to be transferred.

Day 3

The neurological status is unchanged and the patient has been successfully mobilized. He is stable with respect to circulation but needs NA supplement to keep MAP above 85.

Respiratory function is somewhat compromised with reduced ability to cough and some secretory stagnation. No infiltration is visible, but right basal atelectasis is visible. The patient receives intermittent CPAP treatment and respiration physical therapy 3 times per day. The patient is febrile with temperature 38,8. CRP of 230 warrants new chest x-ray and consideration of antibiotics. The patient can eat and drink. The kidney function is good and lactulose (a stool softener) is given to speed up bowel movements. It is noted that contact with Sunnås should be initiated to discuss transfer of patient.

Day 4-8

The condition is improving and the patient is reported as having good respiration while receiving physical therapy and prophylactic CPAP. The CRP remains above 200 but the temperature has been going up and down. The MAP limit of 85 is discontinued and Kabiven and Lactulose treatment is maintained.

Day 8

The patient is transferred to Sunnås.

At Sunnås the patient is experiencing deteriorating respiration and after a week they are forced to transfer the patient to an intensive care unit at a local hospital. When the respiratory function improves, the patient must wait for another available bed. The transfer from Ullevål was probably premature, however, the cost of operating an ICU bed is such that they must select the patients carefully.

Patient history # 2

Day 0

A collision between motorcycle and truck with high estimated speed. The operator of the motorcycle was wearing protective gear and is awake with a GCS of 14-15. He is complaining of pain in neck, back, left shoulder and right arm. He is intubated prior to transportation and arrives at Ullevål + 2,5 hours on a backboard with stiff cervical collar. Circulation and respiration has been stable with 1000ml ringer. He has been observed moving all four extremities prior to intubation.

Vital signs are stable with BP 106/60 and HR of 90. The patient is somewhat hypothermic with a temperature of 35,4 degrees. There is a minor swelling on the basal left side of neck, and thoracic contusion marks on upper left side. There is abnormal respiration sounds across both lungs, but most notably on the left side. Clavicle is fractured on the left side. Injury to lower right arm indicates fracture and there is an open injury on the right hand between the 4 and the 5 finger.

Chest x-ray confirms left side lung contusion, hemothorax and right side atelectasis. FAST is negative and fractures in arm and hand are confirmed. CT shows lateral mass fractures between TH 1 and TH 4 as well as a sternum fracture and a hematoma in mediastinum. CT angiography rules out rupture and dissection of aorta and major vessels.

Drainage of thorax is initiated and 500 ml of blood is drained. The neurosurgeon clears the cervical spine signalling that the collar can come off. The patient is transferred to the ICU for monitoring and awaiting surgery to the arm. He has a tendency to become somewhat hypotensive. The neurosurgeon notes that the patient no longer requires attention from their department.

Day 1

The fractures to the arm and hand are repositioned and fixated. Thorax drainage continues. The BP is susceptible to sedation. The patient is no longer hypothermic. Continued intubation.

Day 2-4

There is no change, however, the neuro-radiologist takes a closer look at the CT scans of the cervical column and finds injury to cervical column not detected initially before the collar was taken off. The C6-C7 injury includes disc and posterior ligament and is assessed as requiring surgery, the collar comes back on. The injuries to the thoracic column are stable. Suddenly the neurosurgeons must be online again.

Day 5

Anterior fixation with CSLP is carried out and injured disc is extracted. Auto transplantation of bone from the hip is carried out. The operation is successful.

Day 6

It is noted by the ICU that although the patient was observed moving both arms and legs at injury site, he was only moving his arms 24 hours later. The neurological status will decide course of action and transfer. Thorax drainage is terminated.

Day 7

The patient is extubated and has sound respiration. He is able to move both arms and legs, but pain in thoracic region prevents him from moving beyond the bed.

Day 8

The patient is transferred to a local hospital awaiting discharge.

This patient was fortunate to escape neurological injuries and did not require the attention of the rehabilitation staff at Sunnås. Rather, a local hospital will provide suitable care until discharge and plan more elementary physical therapy should it be needed for the arm and hand injury.

It is interesting to note that the neurosurgeon alone, alternatively in cooperation with the radiologist, may terminate collar treatment according to the trauma manual. In this case it was terminated prematurely, however, the patient seemed to avoid mounting secondary injuries from undue mobilization.

Furthermore, this example illustrates the challenge of determining all relevant injuries immediately. We should bear in mind that 10% of all vertebral injuries show a second non-consecutive vertebral injury.

Patient history # 3

Day 0

The patient is the passenger on a motorcycle that hits a car at high speed. The driver is killed instantly. She is observed moving both arms and legs initially on site and transported to a local hospital on a backboard and outfitted with a stiff neck. She complains about thoracic pain. She communicates in English and claims only to be visiting Norway. The patient is awake with systolic pressure of 90 and 98% saturation. Chest x-ray is assessed as negative. There is a clinical distal tibia fracture that is immobilized. The peripheral circulation is good. There are no other obvious injuries.

The medivac is redirected from the accident site to the local hospital to which the patient was initially sent. During transportation, the patient has somewhat unstable circulation with BP varying between 80 and 100 systolic. She is given Fentanyl and Ketamin for pain relief. She is handed over to the trauma team at Ullevål approximately two hours after the accident.

Her BP is 90/80 and HR of 88. Respiration is symmetrical, however, thoracic motion is not in accordance with respiration.

Chest x-ray shows a dislocated right shoulder and undecided pathology in several thoracic vertebrae. CT findings include: Caput negative, C5 fracture and dislocation, crushing injury to Th4 and Th5, abdomen negative with respect to fluid. There are no findings for liver, spleen and pancreas.

The distal tibia fracture is operated with external fixation and the thoracic fractures will be scheduled for surgery.

Day 1

Patient is observed in ICU.

Day 2

The surgery of the injuries to Th 4,5 and 6 is undertaken using Universal Spine System (USS) fixation. There is noted damage to the spinal cord. She receives prophylactic treatment with antibiotics.

The neurosurgeon notes that she soon can be mobilized, and that with respect to the column injury can be transported to her home country respiration and circulation permitting.

Day 3

The patient is reported stable with some NA support for MAP above 65. Chest x-ray shows no sign of pneumothorax. CT of thoracic column injury is reported satisfactory. Drain from surgery wound is removed, however, thorax drainage is maintained.

Day 4

There is reduced need for NA support. Sedation is terminated temporarily to test mobility and function. Motion has been observed in both arms, but not in legs. There seem to be no sensory function in the legs. Upon contact the patient becomes wary and respiration rate increases. There is bilateral atelectasis and hematomas in both lungs, however, the patient is cleared for transport by thoracic surgeon.

Day 5

The patient is picked up by GMS and transported by air to her home country.

This patient would most likely have gone to Sunnås if she resided in southern Norway. She is initially taken to a local hospital, but the injuries were such that the trauma team at Ullevål was alerted. Here is yet another example of multiple discontinuous fractures, which is found in 10% of patients with cervical column injuries. In this case the cervical injuries were classified as stable and collar treatment was preferred. The injuries to Th4 and Th5 however, required surgery. It further illustrates the complexity in diagnosis and of determining the level of paralysis and functional deficit in the patient. At first she was able to move both arms and legs, however, by the time she had been operated, sensory and motor function in the legs had been lost. It is possible that an accurate diagnosis as well as the extent of her handicap will reveal itself much later.

Appendix 2 The Glasgow Coma Scale

Assessment area	Score
Eye opening (E)	
Spontaneous	4
To speech stimuli	3
To pain stimuli	2
None	1
Best Motor Response (M)	
Obeys commands	6
Localizes pain	5
Normal flexion (withdrawal)	4
Abnormal flexion (decorticate)	3
Extension (decerebrate)	2
None (flaccid)	1
Verbal response (V)	
Oriented	5
Confused conversation	4
Inappropriate words	3
Incomprehensible sounds	2
None	1

GCS Score = (E+M+V) Best possible score = 15; Worst possible score = 3.

Interpretation:

Score	Severity
14-15	None or mild injury
9-13	Moderate injury
3-8	Severe injury

Source: The ATLS manual 7th edition

Appendix 3 Trauma Alarm information chain:

Injury site to the communication center (AMK)

AMK to ER coordinator

ER coordinator to trauma team on duty

Trauma Alarm Criteria:

Evidence of serious injuries...

- Penetrating gun or stab wounds to head, neck, torso or abdomen
- Penetrating gun or stab wounds to arm above elbow
- Penetrating gun or stab wounds to leg above knee
- Evident significant bleeding
- Evident significant crushing injuries
- Dislocated pelvic injuries
- Two or more large fractures
- Loose ribs "Flail chest"
- Burns covering more than 15% of body surface
- Burns with inhalation injuries

Evidence of unstable patient...

- Disturbed respiration: Dyspnoic, tachy-or bradypnoic
- Hypotension
- Significant reduced conscience

Evidence of exposure to significant energy...

- Other passengers / driver killed
- Patient trapped in vehicle
- Vehicle compartment deformed
- Passengers or driver thrown out of vehicle
- Pedestrian thrown onto/over vehicle or into the air
- Children hit at speed in excess of 30 km/t
- Falls from heights in excess of 5 meters (second floor)

Source: Trauma Manual Ullevål sykehus, August 2006

Appendix 4. ASIA Scorecard

Patient Name _____ Date/Time of Exam _____

Examiner Name _____

ASIA **STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY** **ISCOS**

MOTOR
KEY MUSCLES (scoring on reverse side)

	R	L
C5		
C6		
C7		
C8		
T1		
UPPER LIMB TOTAL (MAXIMUM) (25) (25) (50)		
Comments:		
L2		
L3		
L4		
L5		
S1		
LOWER LIMB TOTAL (MAXIMUM) (25) (25) (50)		
TOTALS (MAXIMUM) (50) (50) (100)		

SENSORY
KEY SENSORY POINTS

0 = absent
1 = impaired
2 = normal
NT = not testable

Any anal sensation (Yes/No) _____
PIN PRICK SCORE (max: 112) _____
LIGHT TOUCH SCORE (max: 112) _____

NEUROLOGICAL LEVEL
The most caudal segment with normal function

COMPLETE OR INCOMPLETE?
Incomplete - Any sensory or motor function in S4-S5

ASIA IMPAIRMENT SCALE

CLINICAL SYNDROMES (OPTIONAL)

☐ Central Cord
☐ Brown-Sequard
☐ Anterior Cord
☐ Conus Medullaris
☐ Cauda Equina

Key Sensory Points

MUSCLE GRADING

- 0 total paralysis
 - 1 palpable or visible contraction
 - 2 active movement, full range of motion, gravity eliminated
 - 3 active movement, full range of motion, against gravity
 - 4 active movement, full range of motion, against gravity and provides some resistance
 - 5 active movement, full range of motion, against gravity and provides normal resistance
 - 5* muscle able to exert, in examiner's judgement, sufficient resistance to be considered normal if identifiable inhibiting factors were not present
- NT not testable. Patient unable to reliably exert effort or muscle unavailable for testing due to factors such as immobilization, pain on effort or contracture.

ASIA IMPAIRMENT SCALE

- ☐ **A = Complete:** No motor or sensory function is preserved in the sacral segments S4-S5.
- ☐ **B = Incomplete:** Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5.
- ☐ **C = Incomplete:** Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.
- ☐ **D = Incomplete:** Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.
- ☐ **E = Normal:** Motor and sensory function are normal.

CLINICAL SYNDROMES (OPTIONAL)

- ☐ Central Cord
- ☐ Brown-Sequard
- ☐ Anterior Cord
- ☐ Conus Medullaris
- ☐ Cauda Equina

STEPS IN CLASSIFICATION

The following order is recommended in determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
2. Determine motor levels for right and left sides.
Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level.
3. Determine the single neurological level.
This is the lowest segment where motor and sensory function is normal on both sides, and is the most cephalad of the sensory and motor levels determined in steps 1 and 2.
4. Determine whether the injury is Complete or Incomplete (sacral sparing).
If voluntary anal contraction = No AND all S4-5 sensory scores = 0 AND any anal sensation = No, then injury is COMPLETE. Otherwise injury is incomplete.
5. Determine ASIA Impairment Scale (AIS) Grade:
Is injury Complete?
NO → **Is injury motor incomplete?**
YES → **Are at least half of the key muscles below the (single) neurological level graded 3 or better?**
NO → AIS=C
YES → AIS=D

If sensation and motor function is normal in all segments, AIS=E
Note: AIS E is used in follow up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact; the ASIA Impairment Scale does not apply.

Source: American Spinal Injury Association

Appendix 5. Spinal Cord Injury Assessment and Management

1. Primary Survey and Resuscitation – Assessing Spine Injuries

Note: Patient in supine position and properly immobilized

- A Assess airway while protect c-spine. Establish a definitive airway as needed.
- B Assess and provide adequate oxygenation and ventilation support as needed.
- C
 - 1 If hypotensive, differentiate between hypovolemic and neurogenic shock.
 - 2 Replace fluids for hypovolemia.
 - 3 If spinal injury is present, fluid resuscitation should be guided by CVP monitoring
 - 4 Assess for rectal spincter tone and sensation.
- D
 - 1 Determine level of consciousness and assess pupils.
 - 2 Determine GCS score.
 - 3 Recognize paralysis / paresis.

2. Secondary survey and Neurologic Assessment

- A Obtain ample history
 - 1 History and mechanism of injury
 - 2 Medical history
 - 3 Identify and record drugs given prior to patient's arrival and during assessment.
- B Reassess level of consciousness and pupils
- C Reassess GCS score
- D Spine Assessment
 - 1 Palpation
 - a. Deformity, or swelling
 - b. Grating crepitus
 - c. Increased pain with palpation
 - d. Contusions, lacerations and penetrating wounds
 - 2 Pain, paralysis, paresthesia
 - a. Presence/Absence
 - b. Location
 - c. Neurologic level
 - 3 Sensation
Testing pin prick sensation in all dermatomes and record the most caudal dermatome with retained pin prick sensation.
 - 4 Motor Function
 - 5 Deep tendon reflexes
 - 6 Document and repeat
Record the neurological examination and repeat motor and sensory examinations regularly until consultation is obtained.
- E Reevaluate-Assess for associated/occult injuries

Source: ATLS Manual, Student Course Manual 7th Edition.

Appendix 6. Summary diagnostic modalities

Conventional x-ray is best for diagnosing skeletal fractures. It is quick and simple and carries a relatively low dose of radiation, but the level of detail offered is low. It is available in many locations and interpretation is of lower complexity than other scans.

CT scanning utilizes the same technology as conventional x-ray, however, it offers much more detailed pictures. Furthermore, it can be used with specific protocols to portray other than skeletal structures. The equipment needed is a lot more elaborate and expensive. This modality also exposes patients to more radiation than conventional x-ray.

MRI scanning utilizes a different technology of magnetic radiation. This type of radiation is harmless compared to x-rays. It is superior when diagnosing soft tissue injuries, however, it too requires elaborate and expensive equipment, and is more time consuming than both conventional x-ray and CT.

Appendix 7. X-ray Identification of Spine Injuries

1. C-Spine X-Ray Assessment

A. Identify presence of all 7 vertebrae and superior aspect of T1

B. Anatomic Assessment

1. Alignment- Identify and assess the 4 lordotic curves

- a. Anterior vertebral bodies
- b. Anterior spinal canal
- c. Posterior spinal canal
- d. Spinous process tips

2. Bone-Assess for

- a. Vertebral body contour and axial height
- b. Lateral bony mass
 - 1. Pedicles
 - 2. Facets
 - 3. Laminae
 - 4. Transvers process
- c. Spinous processes

3. Cartilage-Assess for

- a. Intervertebral discs
- b. Posterolateral facet joints

4. Soft tissue spaces-Assess for

- a. Prevertebral space
- b. Prevertebral fat stripe
- c. Space between spinous processes

C. Assessment guidelines for detecting abnormalities

1. Alignment-Assess for

- a. Loss of alignment of the posterior aspect of the vertebral bodies-dislocation
- b. Narrowing of the vertebral canal-spinal cord compression

2. Bone-Assess for

- a. Bony deformity- compression fracture
- b. Fracture of the vertebral body or processes

3. Soft tissue spaces-Assess for

- a. Increased prevertebral soft tissue space-hemorrhage accompanying spinal injury
- b. Increased distances between spinous processes at one level-torn interspinous ligaments and likely spinal canal fracture anteriorly

Source: ATLS Manual, Student Course Manual 7th Edition

Appendix 7 continued. X-ray Identification of Spine Injuries

2. Thoracic and Lumbar X-Ray Assessment

A. Anteroposterior View-Assess for

1. Alignment
2. Symmetri of pedicles
3. Contour of bodies
4. Height of disc spaces
5. Central position of spinous processes

B. Lateral View- Assess for

1. Alignment of bodies / angulation of spine
2. Contour of bodies
3. Presence of disc spaces
4. Encroachment of body on canal

Source: ATLS Manual, Student Course Manual 7th Edition.

Appendix 8. Denis and Magerl Classification schemes

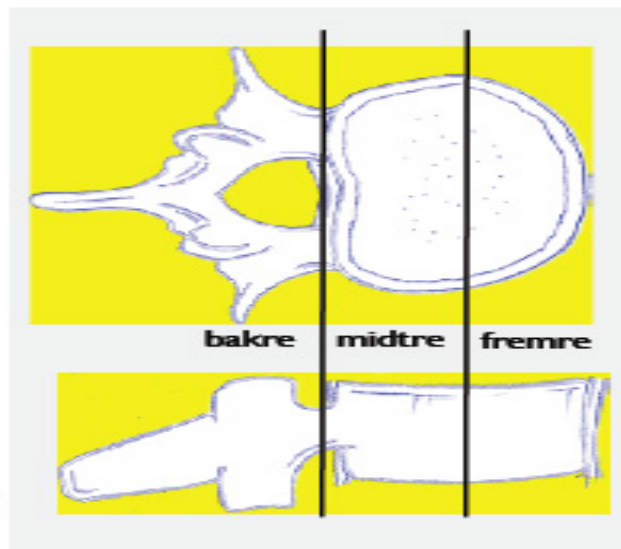


Fig 8.2
Tresøyleprinsippet
fra Denis

Anterior column: Anterior part of vertebral body with ligament and disc.

Middle column: Posterior part of vertebral body with ligament and disc.

Posterior column: Pedicles, facets, ligaments, laminae, spinosi.

Instability when more than one column is compromised.

Appendix 8b. The ABC based on a 2 column model by Magerl et al.

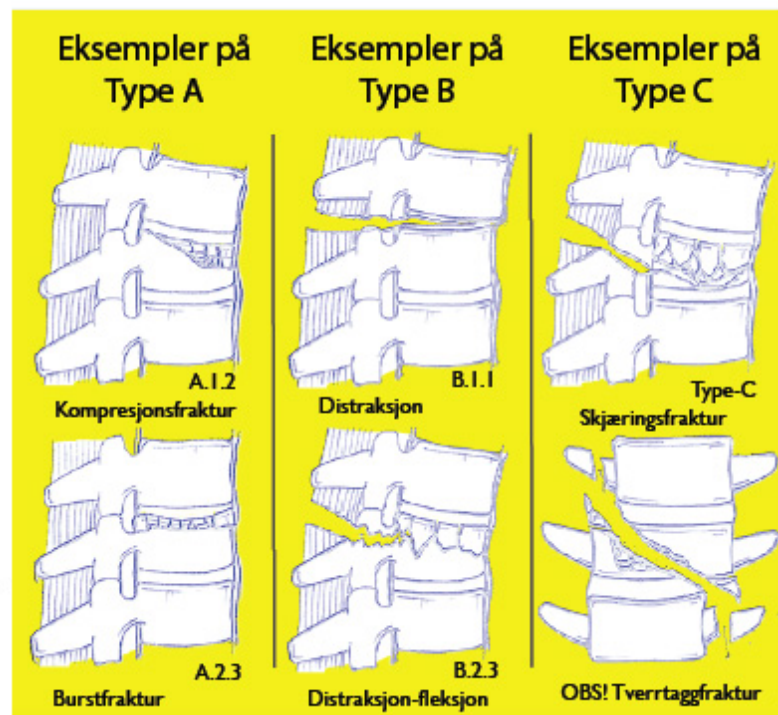


Fig 8.3
Ryggfrakturerdeles
inn etter ABC-
prinsippet. Her er
noen eksempler.

Group A. Compression fractures (anterior part of vertebral body fails in compression)

Burst fractures (anterior and posterior part of vertebral body fails in compression)

Group B. Chance fractures (posterior column fails in transverse tension)

Group C. Complex shearing, rotational injury (failure of lateral process in addition to anterior or posterior column).

Source: Avansert Bruddbehandling Kapittel 8, Madsen / Flugsrud 2005.

Appendix 9. Thoraco Lumbar Injury Severity Score (TLISS)

1. Injury Mechanism: worst level is used and injury is additive
(eg. A distraction injury with a burst component without lateral angulation would receive 1 simple compression + 1 burst + 4 distraction = 6)

Description	Qualifier	Points
a. Compression	Simple compression	1
	Lateral angulation >15 degrees	1
	Burst	1
b. Translation/rotational		3
c. Distraction		4

2. Posterior longitudinal Ligament disrupted in tension, rotation or translation

a. Intact	0
b. Suspected / Indeterminate	2
c. Injured	3

3. Neurological Status

Nerve root involvement	2
Cord, conus medullaris involvement	
Incomplete	3
Complete	2
Cauda Equina involvement	3

Interpretation: The points are added for the 3 components A score of ≤ 3 suggest non operative treatment, a score of 4 suggest operative or non operative treatment and a score of ≥ 5 suggest operative treatment.

The TLICS was constructed as an adaptation of the TLISS in response to surgeons arguing over proposed injury mechanisms, and consequently only morphology of the injury is needed. As a substitute for point 1 above the following points will be assigned.

a. Compression	1
b. Burst	+1
c. Translational / rotational injuries	3
d. Distraction injuries	4

Note: in the event of evidence of two distinct morphologies present, the highest scoring morphology will be used.

Source: Alexander R. Vacaro et al. Spine 2005.

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